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A RESEARCH AGENDA FOR FIRE PROTECTION ENGINEERING

M. Hurley

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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A RESEARCH AGENDA FOR FIRE PROTECTION ENGINEERING

Prepared for
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Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899

By
M. Hurley
Society of Fire Protection Engineers
Bethesda, MD 20814

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William M. Daley, Secretary
Technology Administration
Dr. Cheryl L. Shavers, Under Secretary of Commerce for Technology
National Institute of Standards and Technology
Raymond G. Kammer, Director

Notice

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A Research Agenda for Fire Protection Engineering

The Society of Fire Protection Engineers

February, 2000

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Executive Summary

On October 21 & 22, 1999 the Society of Fire Protection Engineers hosted a workshop to develop a research agenda for the fire protection engineering profession. The 70 attendees came from around the world and from all segments of fire protection engineering practice: consulting, insurance, education, research, manufacturing, enforcement and facilities management.

Fire protection engineers are the link between fire research and its application in the built environment. In this capacity, fire protection engineers have a unique perspective on where fire research is needed. The workshop attendees identified research priorities in four areas:

- Increased utility of risk concepts. Workshop participants noted that consideration of the probabilistic aspects of fire could yield significant improvements by better focusing fire protection resources where they are most needed. An improved understanding of the aspects that affect individual and societal risk acceptance is desired. Also, a framework is needed to apply risk analysis in fire protection design.

- Increased understanding of fire phenomena. Workshop participants identified that research is needed in such areas as heat release rates from fires in buildings, fire detection, and fire suppression. Workshop attendees also emphasized that an improved understanding in this area alone is not sufficient; the results of research must be translated into practice, such as by the development of readily usable models.

- Human behavior. Workshop attendees noted that better considering human behavior in fire would lead to improved fire protection designs. An increased understanding of human behavior and psychology would help fire protection engineers better predict how and when building occupants react to fire cues, such as smoke and alarms. It was also noted that not all people behave the same, and an understanding of how human behavior varies is needed.

- Data. Workshop participants expressed a strong need for data, with known confidence, in all areas considered in fire protection design: reliability data, human behavior, product, failure, near-miss, etc. This data would form the input to fire hazard or risk calculations. Increased availability of data would lead to improved, more cost efficient designs, increased reliability and a better understanding of financial losses and the costs of fire protection. Workshop attendees also stressed that data must be readily available.

Workshop attendees also gave their perspectives on the necessary components of a plan for implementing the research agenda. They noted that a champion is needed, that funding should come from private/public sector partnerships, and that collaboration, including international collaboration, will be necessary. The latter point is particularly true since several of the research areas identified will require input from outside of the traditional fire protection community.

Completion of the research identified in this research agenda will contribute towards improved fire safety and reduced fire related costs.

Acknowledgements

This research agenda is the product of all of the participants in the SFPE Research Agenda Workshop. Their time and effort in developing this agenda is greatly appreciated. A complete listing of all of the workshop participants can be found on page 47.

A steering committee oversaw the development of this agenda, framed the discussions at the workshop and provided the seed crystal for the agenda itself. Their selfless contribution of time and talent was instrumental in the success of the workshop and the quality of the agenda. The steering committee was comprised of the following members:

- James Quiter (chair), The RJA Group
- Philip DiNenno, Hughes Associates
- Paul Fitzgerald, FM Global
- John Hall, National Fire Protection Association
- David Lucht, Worcester Polytechnic Institute
- James Milke, University of Maryland
- Robert Schiffiliti, R.P. Schiffiliti Associates
- J. Kenneth Richardson, Ken Richardson Fire Technologies
- Robert Weber, Clark County, NV

There were five breakout groups at the workshop. Breakout group leaders facilitated discussions that led to the content of this agenda and kept their groups focused. The breakout group leaders were:

- Paul Heilstedt, Building Officials and Code Administrators, International
- Michael O'Hara, The Mountainstar Group
- Matti Kokkala, VTT Building Technology
- Paul Shipp, USG Corporation
- Robert Schiffiliti, R.P. Schiffiliti Associates

Keynote presentations were given by:

- J. Joseph Moakley, U.S. House of Representatives (Massachusetts, 9th District)
- James Quiter, The RJA Group
- Paul Fitzgerald, FM Global
- John Nutt, Ove Arup & Partners & Chair, Fire Code Reform Centre

Morgan Hurley, SFPE Technical Director, served as overall project manager. Additional staff support was provided by Kathleen Almand, SFPE Executive Director, Brian Meacham, SFPE Research Director and Judy Fantle, SFPE Administrative Assistant.

The National Institute of Standards & Technology provided financial support (Grant No. 60NANB8D0047) and secured the Department of Commerce facilities where the workshop was held.

Introduction

"Fire protection engineering" is the application of scientific and engineering principles to protect people and their environment from destructive fire. As the primary appliers of fire protection research, fire protection engineers form one of the principal links between researchers and the end users of fire protection technology.

Fire protection engineering utilizes fire prevention, passive and active fire protection measures, and evacuation strategies to provide the safety required by society at a reasonable cost. Other strategies such as fire safety education, training and fire service response are also used, although other professional groups such as the educational, environmental and legal communities are more active in these areas.

Every profession must strive to find better, more cost effective methods to achieve its goals, and fire protection engineering is no exception. However, there are limited resources available to finance fire related research, which makes it necessary to ensure that the research that is conducted will have the greatest impact. Fire protection engineers, as the primary appliers of fire protection technology, have an understanding of the areas where technology development is most needed.

On October 21 & 22, 1999 the Society of Fire Protection Engineers hosted an international workshop to develop a research agenda for fire protection engineering. The 70 attendees came from around the world and from all segments of fire protection practice: consulting, insurance, education, research, manufacturing, enforcement, and facilities management. The purpose of the workshop was to identify research needs of the fire protection engineering community.

Throughout the world, there are changes occurring that will facilitate the timely implementation of research results. The acceptance of performance-based fire protection engineering is becoming more widespread. Several countries have adopted or are in the process of adopting performance-based fire protection engineering methodologies, including Australia, New Zealand, the United Kingdom and the Nordic countries[1]. In the U.S, a performance-based option has been included in the National Fire Protection Association's *Life Safety Code*[2] and a new *International Performance Code*[3] is expected to be completed shortly. Additionally, the Society of Fire Protection Engineers has published a performance-based fire protection engineering design guide[4] to facilitate the implementation and use of these performance codes.

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[1] Meacham, B. "The Evolution of Performance-Based Codes and Fire Safety Design Methods," *NIST-GCR-98-761*, National Institute of Standards and Technology, Gaithersburg, MD: 1998.
[2] NFPA 101, *Life Safety Code,* National Fire Protection Association, Quincy, MA: 2000.
[3] International Code Council. *International Performance Code,* International Code Council, Falls Church, VA (under development).
[4] Society of Fire Protection Engineers. *The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*, Society of Fire Protection Engineers and National Fire Protection Association, Bethesda, MD: 2000.

WHY RESEARCH IS NEEDED

The innovation gained through research can be implemented to reduce direct and indirect fire related costs, improve life safety, improve international competitiveness and facilitate regulatory reform. Improvements are needed in many areas:

- **Improved Life Safety.** Fire death rates among the elderly and physically and mentally disadvantaged populations are disproportionately high. Changes are occurring in the demographics of the population that will exacerbate this problem. People are living longer, and the elderly will constitute a larger percentage of the population. Accessibility laws will lead to a greater integration of physically and mentally disadvantaged into the built environment. In the U.S., the overall fire death rate relative to population is among the highest in the industrialized world.[5] Additionally, fire injury rates can be several times greater than death rates, with approximately five times more injuries than deaths annually in the U.S.[6]

- **Reduction of fire related costs**. The cost of fire and fire protection – combining spending to prevent or mitigate losses with human and property losses – within developed (G7) countries, constitutes a large percentage of gross domestic product[7]. For example, despite dramatic loss rate declines over the past century, the total cost of fire in the USA is particularly high, estimated at $100 to $200 billion a year[8], or over 2% of the gross domestic product.

- **International Competitiveness**. In Europe and the Pacific Rim, fire protection is typically 2-3% of construction cost.[5] In the U.S., this cost is higher, as approximately 5% of every U.S. construction dollar is spent on built-in fire protection[8]. This high cost of fire protection in buildings is passed on to product costs, which can have a negative effect on competitiveness with countries where the cost of fire protection in buildings is lower.

- **International trade**. The cost in the U.S. of meeting fire safety product standards, including testing to demonstrate compliance, is estimated at more than $25 billion per year[8]. Multi-national firms face this cost repeatedly in global markets with varying standards. Less reliance on prescriptive, pass-fail standards will allow producers to test once and sell anywhere. However, development of harmonized, performance-based testing standards requires research, data, and tools to demonstrate equivalence of tests and to convert test results between systems.

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[5] Wilmot, R.T.D. (Ed.), "United Nations Fire Statistics Study,", London: World Fire Statistics Centre, September 1998.
[6] *Fire in the United States*, United States Fire Administration, 10th Ed., 1995.
[7] Tudhope, H., "International Fire Losses" 1985-1987, *Fire Prevention*, May 1989.
[8] Hall, J., The Total Cost of Fire in the United States Through 1995, NFPA Fire Analysis & Research Division, Quincy, MA, March 1998.

- **Regulatory reform.** The industrialized world is adopting performance-based codes for fire safety design. Performance-based design requires engineers to seek out and appropriately apply engineering tools not contained within the codes. Uncertainties in predictions from these tools are often undocumented, and appropriate safety factors often have not been identified or substantiated. Without a strong scientific foundation, which is developed through research, designs with weak scientific underpinnings may be developed and implemented. These may be less expensive, but possibly less safe and no more innovative.

- **Protection of the Environment.** Fire can have a detrimental impact on the environment by introducing toxic or hazardous materials. Products used for fire protection, such as fire suppression agents, must continue to meet changing environmental requirements. Research can be used to identify fire protection measures and products that are environmentally benign.

In a myriad of ways, fire protection engineers would benefit from additional science and tools that would help them advance safety, reduce construction costs, and support innovations in product and building design. Fire protection engineering technology is changing to favor explicit calculation and scientific demonstration of fire performance over prescriptive approaches.

It is therefore essential that the research base for fire protection engineering be strengthened. Current resource limitations demand that this be done efficiently and effectively. This research agenda identifies the research that is most needed by the fire protection engineering community to make meaningful gains in the areas identified above.

Workshop Summary

The workshop was held for 1-1/2 days, beginning in the morning of October 21, 1999. Following welcoming remarks and a summary of workshop goals, keynote presentations were given by Joseph Moakley, U.S. Congressman representing Massachusetts' 9th district, James Quiter, Senior Vice President of the RJA Group, and John Nutt, ex Chair of Ove Arup & Partners and Chair of the Fire Code Reform Centre. These presentations were intended to help participants focus their thoughts on research needs and the benefits of fire research. Participants were then divided into five breakout groups. Each breakout group was comprised of a cross section of the workshop attendance. Each breakout group met three times, and each meeting had a different goal.

The first time that breakout groups met, participants were asked to brainstorm fire protection problems that they had encountered in the course of their work. In the second meeting of the breakout groups, research needs were identified that would help overcome the problems identified.

Following the second meeting of the breakout groups, the plenary session was reconvened. A keynote presentation was given by Paul Fitzgerald, Executive Vice President of FM Global on the benefits of fire research to business and on how those benefits are often long in coming and difficult for businesses to recognize. The breakout groups then met for a third and final time on the morning of the second day to prioritize the needs that they identified and give their perspectives on implementation of the research agenda.

The workshop concluded with a plenary session where each of the breakout group chairs presented the research needs that their group identified as the highest priorities. The results of the breakout group discussions were summarized and agreement reached on the highest needs. The workshop attendees identified four primary areas where research is most urgently needed:

- Fire phenomena
- Human behavior
- Risk
- Data

Forms were given to workshop participants for them to evaluate the impact, cost, feasibility and timeframe for the research needs identified at the workshop. These forms were completed after the workshop and returned to the workshop host.

The next four chapters of this research agenda summarize the discussions at the workshop regarding the research needs in each area. Each chapter concludes with a table that lists the research needs identified. The tables also summarize the results from the evaluation forms.

Risk Management

The engineering community generally recognizes risk as a product of probability and consequence. However, risk is much broader than this simple equation suggests, for example, addressing issues of uncertainty.

Fire protection engineering has typically focused only on the consequence (or hazard) part of risk. To bring about significant cost-benefit improvements in fire protection engineering design, and to better focus fire protection resources where they are needed most, it is necessary to apply risk management. Using risk management in fire protection engineering practice requires definition of the level of risk that society is willing to accept and a risk management framework.

Society is willing to accept a certain degree of risk. However, exactly how much risk society finds acceptable is unknown. Compliance with prescriptive codes and standards is intended to provide an "acceptable" level of safety. However, as more detail and new requirements are added to prescriptive codes, it becomes more difficult to explicitly define what is considered an acceptable risk.

Reduced risk tends to mean increased cost. Less risk is typically viewed favorably. However, as risk decreases, the costs involved in providing still lower risk eventually become unacceptable. Determining what level of risk is acceptable to society involves finding where the balance occurs between how much society is willing to pay to avoid risk, and the risk itself. Additionally, risk acceptance is not universal – some communities may be willing to accept a higher level of risk, and others may be less willing to pay for a lower level of risk. Moreover, the costs and risks often fall on different people, and this further complicates the search for a single value for acceptable risk.

Present application of performance-based design typically focuses on measuring "equivalency" to individual code or standard provisions. However, without specific risk targets, equivalency determinations can result in an inconsistent level of safety. People may interpret the intent of a provision differently. Similarly, judgement is needed to select the appropriate fire scenarios in order to test a proposed alternative design. A less severe scenario can result in a less safe design being considered acceptable; similarly, a scenario that is too severe might result in a design that is not cost effective.

One workshop participant noted that "it is not possible to incorporate society's perception of acceptable risk into design, particularly as perception of 'acceptable risk' varies." Determining what constitutes an acceptable risk will require the input and concurrence of public policy makers. Since definition of risk involves deciding how much loss is acceptable, this can be a politically challenging task. However, lessons can be learned from other industries, such as the automobile and aircraft industries.

Once an acceptable level of risk is known, it will become necessary to design to meet this level of risk. This will require the development of a risk analysis framework that considers the risk exposure and the costs, both initial and lifecycle, of any protection methods used.

The development of a risk analysis framework for fire protection would bring many benefits. In addition to maximizing cost effectiveness of fire protection designs by designing to meet the risk that is acceptable to society, a risk analysis framework would allow consideration of the effectiveness of fire protection designs as a complete system. The contribution of individual components (such as active and passive systems, the fire service, fire prevention, and fire safety education) could be considered collectively.

As risk analysis has been applied in other engineering disciplines, one can look to these disciplines as a starting point. The risk analysis tools used in other engineering disciplines can be evaluated for their applicability to fire protection engineering, and possibly modified accordingly.

Research Needs: Risk Management

Research Need	Benefits	Impact on Need (1 = no impact; 5 = high impact)	Cost (1= high cost; 5 = negligible cost)	Feasibility (1 = very difficult; 5 = simple)	Time (1=5 or more years; 5 = 1 or fewer years)
Determine what level of risk is acceptable to society, and how acceptable risk varies from community to community.	• Understand the level of safety society desires, and the costs of providing this level of safety. • Understand how much society's risk acceptance varies in different communities.	4	2	3	2
Develop a risk management framework to describe the fire/building/people interaction and impact of system operation success or failure.	• The ability to provide the level of safety that society requires at the most reasonable cost. • The ability to balance the strengths and weaknesses of individual components of a fire protection strategy.	4	3	3	2

Fire Phenomena

A common issue in the breakout groups was that "gaps in current design methods result in excessive conservatism."

An understanding of fire phenomena forms the foundation upon which engineered fire protection is based. Consideration of the effects of fire on people, buildings, property or the environment first begins with consideration of the types of fires that might be expected and how those fires would behave (fire growth, heat release rate, smoke production, etc.). While there are significant opportunities for improvement in design that would result from research in other areas, strengthening the knowledge base in fire phenomena would lead to improvements in all designs.

Current predictions of fire phenomena are too often based on rules of thumb, extrapolation from small scale testing or expensive large scale testing. While these methods are based on a significant body of experience, the margin between predictions and actual behavior is often unknown, and the applicability of these methods to new fire hazards, new technologies, and any changes in the future, cannot be assumed.

Fire development is typically categorized into three regimes: growth, full development and decay. Typically, fire growth is assumed to be proportional to time squared. While this method has been used successfully for quite some time, it is based on limited testing and may not apply to all configurations. In some cases, more scientifically grounded predictions are possible where test results from burning individual pieces of furniture can be aggregated and balanced against the available ventilation.

Methods of predicting heat release rates from fully developed fires are relatively well established where the enclosures are approximately the size of a common office. However, these methods do not hold well for larger or elongated enclosures. The ability to predict heat release during the decay period is very limited, but the decay period is typically of little consequence for fire protection design.

Methods currently exist for predicting the response of detectors, but these methods are limited to thermal detectors that are installed under horizontal, unobstructed ceilings. Prediction methods are needed for detectors that are installed in other geometries. Also, smoke detector response is typically predicted assuming a temperature rise necessary for operation, a method that does not have a strong scientific basis. While these methods have worked reasonably well, a more detailed understanding would be beneficial such that detection system design and performance could be better matched with design objectives.

In the area of fire suppression, there has been a fair amount of research into halon alternatives and water mist; however, a quantitative understanding of fire suppression is still lacking in most areas. The minimum water application rates from sprinkler systems, which are the most widely used suppression systems, to achieve fire suppression or control are unknown in all but a limited number of cases. Research is needed to better predict suppression system efficacy.

However, a greater understanding of fire phenomena in itself is not sufficient. It is necessary to transfer knowledge gained through research into fire protection engineering practice through the development of models and other tools. A greater understanding of fire phenomena which is readily applicable through models will lead to better and more cost effective fire protection.

Research Needs: Fire Phenomena

Research Need	Benefits	Impact on Need (1 = no impact; 5 = high impact)	Cost (1= high cost; 5 = negligible cost)	Feasibility (1 = very difficult; 5 = simple)	Time (1=5 or more years; 5 = 1 or fewer years)
Heat release rates (fire growth & fully developed fires)	• Better prediction of fire protection performance • Stronger underpinning of fire protection designs • Better predictions of the effects of fire • Improved protection of people and property	4	1	2	2
Suppression system effectiveness	• Better prediction of suppression performance • Suppression system designs could be more closely matched with expected fire characteristics • Improved protection of people and property	4	2-3	2	2
Response of fire detectors (smoke, heat, flame, etc.) to different fire signatures	• Better prediction of detector response • Detection system designs could be more closely matched with expected fire characteristics • Improved protection of people and property	2	3	3	3
Smoke movement from low energy (smoldering) fires	• A better understanding of a type of fire that can be difficult to protect against	2	3	3	3
Investigate the impact of fire and fire protection on the environment	• Reduced environmental damage from fire and fire protection	2	3	3	3

Research Needs: Human Behavior

A participant in one of the breakout groups noted that "fire protection system designs assume that people will leave buildings in the event of fires. However, this often does not happen; ... we need to design for these actions." Similar remarks were made in each of the other breakout groups.

Designs that are based solely on fire behavior, equipment performance, and materials response overlook a significant factor that can often by the key to the outcome of a fire: human behavior, human performance, and human response. To provide better life safety, it is necessary to better understand the actions that people will take in response to a fire.

The decisions that people are likely to make in response to a fire and the reasons for those decisions are not well understood. Most designs are based on the assumption that people would leave immediately after being notified of a fire. However, research has shown that people frequently take other actions before evacuating, such as investigating, notifying others or looking after family members.

While there is a significant body of research on movement speed during evacuation, there is little understanding of how to predict pre-movement times, i.e., the time from the onset of hazardous conditions to the time when occupants begin evacuation. These pre-movement delays have been significant in many cases. Increased understanding of human behavior and psychology is needed to better predict how and when building occupants react to fire cues, such as smoke and alarms, and what actions they take upon recognizing a cue.

The fire environment can also impact human behavior. People may become impaired or incapacitated from exposure to toxic fire products. Decreased visibility thorough smoke can affect decision making. While there is knowledge concerning the impact of combustion products on human capability, survivability, and behavior, most of it is based on animal testing for lethal effects. Sub-lethal health effects, effects on behavior, and animal-to-human conversions are among the points not now well understood.

Considering human behavior in design is complicated by variations in the behaviors of different people. People in family settings may put the safety of other family members above their own. People with mobility or sensory limitations might react differently than people without impairments. People might have varying degrees of consciousness, particularly where they could be expected to sleep. These occupant factors, and their implications on design, need to be better understood.

As with fire phenomena, increased understanding of human behavior in fire must be quantitative and predictive. Readily available models will be needed to facilitate the consideration of human behavior in engineered fire protection system design. An increased understanding of human behavior in fire will lead to more efficient life safety systems, thus providing necessary protection at acceptable cost.

Research Needs: Human Behavior

Research Need	Benefits	Impact on Need (1 = no impact; 5 = high impact)	Cost (1= high cost; 5 = negligible cost)	Feasibility (1 = very difficult; 5 = simple)	Time (1=5 or more years; 5 = 1 or fewer years)
Human behavior in fire, including responses to cues, pre-movement decision making and the impact of fire products (heat, gasses, etc.) on behavior.	• Better understanding of how people will react to fire and the actions that they will take • Better understanding of how people are affected by exposure to fire and fire effects	5	3	3	2
Develop design methods based on human behavior in fire situations.	• Egress system design could be matched to the expected actions that people might take • Improved life safety designs	5	3	3	2

Research Needs: Data

Each of the breakout groups expressed concern with the paucity of data that is available to fire protection engineers. Statements made included: “A significant amount of fire testing is conducted; however, the results from these tests are not readily available,” and “forensic research is needed to capture performance data of real fires.”

Data forms the input to engineering tools and calculations. Data is needed to assess how products and materials would behave in fires. Reliability data is needed for fire protection systems. Forensic data is needed to learn more about how fires are started and for feedback regarding failures and successes. Human behavior data is needed to learn more about what types of people can be expected in different occupancies, and what types of actions they might take that could lead to fires or alter the course of fires.

There is currently a significant amount of testing conducted to evaluate products. However, the data resulting from these tests are often unavailable or proprietary. In the absence of readily available product data, engineers are faced with applying engineering judgement or making assumptions regarding how products might behave. Mechanisms must be sought to remove proprietary concerns, or incentives must be created to promote the sharing of product data.

Fire protection systems are not always operational. A fire protection system may be unavailable due to accidental shutdown or maintenance. A fire protection system may be available, but might still not perform as intended. Data is needed regarding availability and reliability of fire protection systems so engineers can better predict their dependability. Additionally, data is needed to learn how the performance of systems change with time and to gain a quantitative understanding of the effects of inspection and maintenance at different intervals and depths. With improved knowledge of reliability and availability, redundancy could be provided where it is needed, and not provided where a component is sufficiently dependable.

Forensic data is needed to provide feedback from fires. An increased availability of forensic data would give additional opportunities to learn which strategies work well and which strategies don’t work well. Forensic analysis could also be used to gain additional insights into frequencies of fire ignitions in different occupancies. While there is considerable useful fire incident data available, the level of detail on all but the largest fires typically falls well short of engineering needs. The full range of scientific investigative techniques are applied to only a few major fires each year, leaving unanswered questions about the details that are provided on many fires. More detail is needed on smaller fires and investigation that is more thorough would be valuable for most fires. Particularly of interest are small fires that would have become large but for mitigating factors.

While many forms of data are needed, all data must be readily available and have known limitations. Workshop attendees suggested establishing a central contact for fire data. This central contact point would not need to physically house data, but could index data that is contained in other locations. Workshop attendees also identified a need to maintain data in such a manner that it can be used with confidence, which would fall to all who collect or store data.

Research Needs: Data

Research Need	Benefits	Impact on Need (1 = no impact; 5 = high impact)	Cost (1= high cost; 5 = negligible cost)	Feasibility (1 = very difficult; 5 = simple)	Time (1=5 or more years; 5 = 1 or fewer years)
Develop a data reporting/collection method such that reliability, failure, near miss, product, and occupant data, with known confidence and limitations, is available to the design community.	• Allow engineers greater access to data • Better prediction of the performance of individual components • Improved protection of people and property	4	2	3	2
Investigate how installations vary from design.	• Better prediction of as-built performance • Improved protection of people and property	3	2-3	2	2
Data collection from post fire analysis.	• Increased feedback from failures and successes • Help overcome gaps in data stemming from proprietary concerns	4	4	4	4
Improve collection of system reliability data from maintenance and inspection	• Better prediction of how components could fail and how frequently failures occur • Improved protection of people and property	5	3	4	3
Determine the effects of aging on equipment performance.	• Better predict how fire protection performance changes over time • Improved protection of people and property	5	2	1	1
Better monitor and manage systems and components that affect building performance.	• Changes that would adversely impact fire protection performance could be avoided (changes in occupancy, changes to fire protection system components, etc.) • Improved protection of people and property	4-5	2-3	3-4	2

Summary & Conclusions

The fire protection engineering community has identified research needs in several areas: Research is needed to apply risk concepts in fire protection design. A better understanding of fire phenomena and human behavior in fire is needed. There is also a need for data in all areas considered in fire protection engineering design.

Realization of the research needs identified in this agenda will allow fire protection engineers to achieve a number of societal benefits: improved life safety, reduction of fire related costs and improved environmental protection. Additionally, others stand to benefit from an increased understanding of the physical world – product manufacturers, building owners, insurers, the fire service and the public at large.

Implementing the research agenda will not be easy. It will require a significant financial investment and several years to achieve it. Presently, there are a number of organizations involved in research, including both private companies and governmental agencies around the world. Each of these organizations will have a role to play in implementing the research agenda.

Many stand to benefit from the results of the research identified in this agenda. Therefore, it is not reasonable to depend only on the organizations now involved in fire research to conduct the necessary research with the resources they currently have available. Collaboration and partnerships will be crucial to the success of implementing this agenda.

Additionally, a champion will be needed to coalesce the diverse interests that will need to come together to ensure successful implementation of the agenda. This champion will need to advocate the agenda, break down inter-organizational barriers, and oversee and monitor completion of agenda topics.

Realization of the research agenda will be no small undertaking. However, the benefits far outweigh the costs. Implementation of the research agenda will bring about significant improvements that will improve safety and reduce fire related costs.

Workshop Attendees

Name	Organization
Vytenis Babrauskas	Fire Science & Technology, Inc.
Mike Balch	Australian Building Codes Board
Carl Baldassarra	Schrimer Engineering Corp.
John Bender	National Association of State Fire Marshals
Craig Beyler	Hughes Associates
Jim Beyreis	Underwriters Laboratories, Inc
Jason Boren	Bechtel
Robert Boyer	Edwards Systems Technology
Doug Brandes	Duke Power
Murray Cappers	J&H Marsh and McLennan
Larry Maruskan	US Fire Administration
Geoff Cox	Building Research Establishment
Dick Crouse	American Petroleum Institute
Richard Custer	Custer-Powell, Inc.
Tom Daly	Hilton Hotels
Robert D'Angelo	U.S. Army
Mr. Ron de Veer	Queensland Department of Communication & Information
Dougal Drysdale	University of Edinburgh
Ken Dungan	Risk Technologies, LLC
Fred Emerson	Nuclear Energy Institute
William Erny	American Petroleum Institute
Lenny Farelo	Intel Corporation
Paul Fitzgerald	FM Research Corp.
Jay Fleming	Boston Fire Department
Arnold Garson	Cerberus Pyrotronics
Casey Grant	National Fire Protection Association
LT Andy Grenier	U.S. Coast Guard
John Hall	National Fire Protection Association
Rich Hansen	U.S. Coast Guard
Paul Heilstedt	Building Officials and Code Administrators, International
Wayne Holmes	Hartford Steam Boiler Professional Loss Control
Tom Jaeger	Gage-Babcock & Associates
Marc Janssens	Southwest Research Institute
Robert Jonsson	Lund University
John Klote	American Society of Heating, Refrigeration and Air Conditioning Engineers

Bill Koffel	Koffel Associates
Matti Kokkala	VTT Building Technology
Bruce Larcomb	Building Officials and Code Administrators International
Larry Little	Commonwealth Scientific and Industrial Research Organization.
Dave Lucht	Worcester Polytechnic Institute
John MacGreggor	Building Industry Authority
Robert Malanga	Union Camp Corporation
Chris Marrion	Arup Fire
John McFassel	U.S. Army Aberdeen Test Center
Joseph Messersmith	Portland Cement Association
Fred Mowrer	University of Maryland
Frederick Mulhaupt	Fire Protection Research Foundation
Bijan Najafi	SAIC
Harold Nelson	Hughes Associates
David Notley	SAIC
John Nutt	Ove Arup & Partners
Michael O'Hara	MountainStar Enterprises
Jim Quintiere	University of Maryland
Jim Quiter	The RJA Group, Inc.
Ken Richardson	Ken Richardson Fire Technologies, Inc
Mickey Reiss	The RJA Group, Inc.
Robert Schifiliti	RP Schifiliti Associates, Inc.
Jim Shields	University of Ulster Fire SERT Centre
Paul Shipp	USG Corporation
Nathan Siu	Nuclear Regulatory Commission
Warren Stocker	Safeway Inc.
Kuma Sumathipala	American Forest & Paper Association
Harry Taback	J&H Marsh & McLennan
William Tangye	Southern Building Code Congress, International
Ian Thomas	Centre for Environmental Safety and Risk Engineering
Jon Traw	International Conference of Building Officials
Beth Tubbs	International Conference of Building Officials
Bob Weber	Clark County Nevada
Dave Wechsler	Union Carbide
Jack Woycheese	Gage-Babcock & Associates

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AUTHOR(S) (LAST NAME, FIRST INITIAL, SECOND INITIAL)

Hurley, M.
Society of Fire Protection Engineers, Bethesda, MD 20814

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On October 21 & 22, 1999 the Society of Fire Protection Engineers hosted a workshop to develop a research agenda for all fire protection engineering profession. The 70 attendees came from around the world and from all segments of fire protection engineering practice: consulting, insurance, education, research, manufacturing, enforcement and facilities management. Fire protection engineers are the link between fire research and its application in the built environment. In this capacity, fire protection engineers have a unique perspective on where fire research is needed. The workshop attendees identified research priorities in four areas: risk concepts, fire phenomena, human behavior and data. Completion of the research identified in this research agenda will contribute towards improved fire safety and reduced fire related costs.

KEY WORDS (MAXIMUM OF 9; 28 CHARACTERS AND SPACES EACH; SEPARATE WITH SEMICOLONS; ALPHABETIC ORDER; CAPITALIZE ONLY PROPER NAMES)

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